technology fusion[1]

Joe Tidd and Tanya Sammut-Bonnici

Technology fusion involves the combination and transformation of a number of different core technologies in order to create new product markets. The term was popularized by Fumio Kodama of Japan's Science and Technology Agency (STA) in the 1980s: *The fusion of technologies goes beyond mere combination. Fusion is more than complementaries, because it creates a new market and new growth opportunities for each participant in the innovation… it blends incremental improvements from several (often previously separate) fields to create a product*.

The key element of technology fusion is that it is both complementary and cooperative. Typically, it is the result of reciprocal and substantial R&D expenditure by companies from a range of industries and with different technological competences. For example, in the last century the fusion of research by companies from the mechanical and electronic engineering sectors created what the Japanese call "mechatronics." A group of Japanese companies from a wide range of industries combined their efforts: Fanuc, a spin-off from the computer company Fujitsu, led the group with the development of an electrohydraulic servomotor and a new controller; Nippon Seiko (NSK), Japan's leading bearing manufacturer, developed a new type of ballscrew; and material suppliers developed a new low-friction coating. This spawned the Japanese robotics and numerically controlled machine tool industries, which now dominate world markets.

The microelectronics industry is at the maturity phase of its silicon-based manufacturing revolution, and is now looking toward the fusion of micro and nano manufacturing technologies. The latest genre of micro products is merging a wide range of resources and knowledge-based technologies that provide intelligent functions in miniaturized products. Micro manufacturers are making use of a wide selection of technologies when manufacturing components. The technologies that are fused into the manufacturing process are mechanical machining, electrochemical machining, electro-discharge machining, beam-based technologies, and lithographic and replicable processes.

Technology fusion is becoming the norm in the manufacturing of miniaturized components. There is no one dominant technology that has taken over the industry. In fact, technology leaps are anticipated from the amalgamation of technologies and their implementation in product manufacturing. Processes that are showing high potential are fusing both mechanical and integrated circuit micro production technologies.

Technology fusion in micro and nano manufacturing is expected to have the greatest growth potential in the surgical, automotive, and biotechnology industries.

Technology fusion is of increasing importance in a wide range of industries in which American and European companies are currently strong. In the telecommunications sector, the fusion of optics and electronics technologies has been critical. In the automotive industry, the integration of electronic and mechanical systems has become a major locus of innovation, particularly in engine, transmission, and braking systems. In aerospace, the development of fly-by-wire systems demands the fusion of electronics and hydraulics technologies – and the next generation of fly-by-light systems will also require expertise in optics technologies.

Significantly, Japanese companies have considerable expertise in electronics, optoelectronics, and hydraulics technologies and appear to be able to recognize and exploit the potential of technology fusion. Japanese companies are reflecting the importance of technology fusion in their slogans and company missions. For example, NEC uses "computers & communication," whereas Toshiba uses "energy and electronics." This is more than marketing alliteration, and reflects an explicit strategy of related diversification.

However, there are a number of potential problems with the concept of technology fusion that must be resolved: the measurement of technology fusion; the level of analysis; and the organizational constraints. The first two issues are closely related. Most of the current analysis of technology fusion has been undertaken at the level of the industry or sector, and has been based on the levels of R&D expenditure. In

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Japan, companies are required to report their R&D expenditure to the government, disaggregated into 31 different product fields. Studies suggest that growing proportion of R&D expenditure lies outside the traditional core business. Two ratios are of particular significance:

$$\frac{\text{R\&D expenditure by industry A in other industries}}{\text{R\&D expenditure by industry A in itself}}$$

and

$$\frac{\text{R\&D expenditure by other industries in industry A}}{\text{R\&D expenditure by industry A in itself}}$$

The ratio of R&D in outside industries to that in the core business can be used as an indicator of technology fusion. Similarly, the R&D from outside industries into an industry as a ratio of the R&D within that industry can be calculated. However, strictly speaking, these ratios may simply indicate diversification; but, by definition, technology fusion involves reciprocal investment by companies in the respective industries. Combining the two ratios for specific pairs of industries provides a better measure of reciprocal investment. For example, a coefficient of technology fusion (CTF) can be defined as follows:

$$\text{CTF} = v\text{R}_\text{A}\text{R}_\text{B}$$

where

$$\text{R\_A} = \frac{\text{Total outside R\&D by A}}{\text{R\&D in B by A}}$$

and

$$\text{R\_BB} = \frac{\text{Total outside R\&D by B}}{\text{R\&D in A by B}}$$

Defined in this way, the closer the CTF is to unity (one), the greater the level of mutual R&D investment. Therefore, one can construct year-by-year fusion maps based on the level of reciprocal R&D investment. Kodama has done this for several periods, and claims to have identified the emergence of mechatronics and biotechnology in the mid-1970s.

In Japan, the MITI now conducts fusion surveys on a periodic basis. However, there are several problems in applying this analysis. First, the standard industrial classification adopted may obscure occurrences of technology fusion. Second, the reliability of data on R&D is uncertain; for example, numerous studies suggest that the definition of R&D is variable, despite the OECD "Frascati" guidelines. Moreover, the precision of allocation into the different product groups is unknown. Third, only aggregate R&D expenditure by principal industries is published outside Japan. Any attempt to allocate to different product groups would have to be based on primary data collection from companies, or estimates from annual reports and other sources.

For these reasons, other measures of technological capability and activity may be more appropriate at the level of the firm. Of the techniques available, patent analysis and bibliometric measurements based on publications are the most promising. Patent analysis will typically involve detailed study of between 1000 and 10 000 patent applications, depending on the company and field of technology. For example, in the United States, 1000 new patents are issued every day. A leading hightech company, such as Hitachi, will be issued almost 2000 patents each year. Patent data can be used in a number of ways, the most common being to measure changes in the number of patents granted in specific fields. In addition, maps of technology fusion and the associated organizational linkages can be generated by examining the cross-citation of related patents.

Finally, there may be significant organizational barriers to technology fusion at the level of the firm. Past strategic choices clearly shape existing organizational structures and processes, and these structures and processes may constrain future strategic options. For example, most large firms are organized into strategic business units (SBUs), based on past product market linkages, but these linkages may no longer be relevant, and may prevent technological synergies across SBUs. This suggests a potential barrier to the recognition and exploitation of technology fusion. Independent strategies to optimize the performance of each division may not necessarily produce optimum corporate performance.

ENDNOTES

[1] Original article by Joe Tidd. Updated by Tanya Sammut-Bonnici.

See also *frugal innovation*; *innovation strategy*; *R&D strategy*; *technology and standards in network industries*

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